ANNEX B

The Principles of Synthetic Aperture Radar[62]

Modern methods of digital signal processing have enabled great improvements to be made to the performance of radar. One of the most powerful of these, known as synthetic aperture radar, overcomes the limitation on angular resolution, which in a conventional radar is established by the size of the antenna, to which there are obvious practical limits, especially in an aircraft or space vehicle.

Synthetic aperture radar uses the motion of the vehicle on which it is mounted, thus taking advantage of the doppler effect. This is a phenomenon associated with wave motion radiated by a moving body, reflected by a moving body, or observed by a moving sensor. Relative motion between the source and the receiver causes the frequency to be changed, by an amount proportional to the relative velocity. A common example is the change in the pitch of the sound from the horn of a speeding railway locomotive as it passes the stationary listener. The doppler effect is observed with electromagnetic waves, so that a moving radar transmitting on a fixed frequency will receive echoes whose frequencies are slightly shifted, by amounts which depend on their relative motions as seem from the radar. If the radar beam is directed sideways to the direction of motion of the vehicle, stationary targets ahead of the radar will be seen as approaching it, while ones behind it will be receding. Only stationary targets exactly abeam of the radar will experience zero doppler shift.

Using the techniques of modern computers, the signals received by the radar are stored over a period of several seconds, during which the vehicle has moved through an appreciable distance, and many pulses have been radiated and echoes returned. By combining the series of pulses received from the same range, and keeping track of their doppler shifts, it is possible to determine the extent in the direction along the track of each reflecting target, with a precision very much better than could have been obtained with a conventional radar with the same antenna aperture. In fact, the resolution is better than that which could have been obtained using a fixed antenna as long as the distance through which the actual antenna was moved during the period over which the signals were integrated.

To match this great improvement in resolution along the direction of motion of the vehicle it is desirable to achieve comparable resolution in the direction across the track. Fortunately, this is not difficult, and can be accomplished either by using very short transmitter pulses or by employing a clever electronic technique known as pulse compression.

In this manner it has become possible to produce radar images of the ground (or the sea, or ice) that compete with photography in their ability to reveal fine detail, and their collection is not dependent on sunlight or clear air. And they have the additional advantage that the resolution is as good at long as at short range.

---

[62] Stimson, pp. 527 - 548.